HARVARD UNIVERSITY

PSYCHO-ACOUSTIC LABORATORY

Memorial Hall Cambridge Massachusetts

PERIODIC STATUS REPORT XXXVIII

Period covered 16 May - 1 December 1961

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51

CONTENTS

PERIODIC STATUS REPORT XXXVIII

PSYCHO-ACOUSTIC LABORATORY

16 May - 1 December 1961

During the past six months the following have been members of the research staff of the Psycho-Acoustic Laboratory.

S. S. Stevens, Ph.D., Director
E. B. Newman, Ph.D., Associate Director
G. v. Békésy, Ph.D., Senior Research Fellow in Psychophysics
J. C. Stevens, Ph.D., Assistant Professor of Psychology
H. Eisler, fil. lic., Research Fellow
T. S. Aiba, Ph.D., Research Fellow
G. van den Brink, Dr.Phil., Visiting Research Fellow
Miguelina Guirao, Ph.D., Visiting Research Fellow
Lois Hammer, M.A., Graduate Student
J. D. Kieffer, B.A., Graduate Student
L. E. McMahon, M.A., Graduate Student
D. W. Panek, B.A., Graduate Student
A. W. Slawson, M.A., Graduate Student
R. Gerbrands, Instrument Maker

RESEARCH COMPLETED

Since the 16th of May 1961 research has been completed and reports prepared on the following subjects. Reprints of these reports should be available within the next few months. A list of recent reports, and their PNR numbers, is included at the end of this report.

PNR-258 The Gap between the Hearing of External and Internal Sounds. G. v. Békésy.

The signal-to-noise ratio of the ear poses many unsolved problems because of the ear's high sensitivity for external sound. There seem to be three systems involved in transforming the large but forceless vibrations of air particles into the smaller vibrations of a stiffer molecular layer: (1) a hydraulic transformer in the middle ear, (2) a shearing force around the hair cells, and (3) a molecular transformer that concentrates all the forces onto a small layer. It is probable that the mechanical displacements are transformed into electrical potentials by a triggering mechanism.

Relevant to this issue are the hearing of one's own voice and the noises in the body of nervous origin. It may be that some form of neural inhibition decreases the importance of these internal noises relative to the external stimulus.

This article will appear in a forthcoming issue of the Journal of Experimental Biology.

PNR-259 The Quantification of Tonal Volume. H. S. Terrace and S. S. Stevens.

Tonal volume is defined as the apparent size or space-filling attribute of a sound. In six experiments groups of 10 subjects estimated the magnitude of the apparent volume of tones selected from the equal-volume contours previously determined by Thomas. For each experiment two cuts, widely spaced, were made across each of five contours. These cuts defined a set of ten tones, each of a different frequency and intensity. In order to check the reliability of the magnitude estimations of volume, the tones from each cut were used in at least two experiments.

In each experiment, one of the two tones from the middle contour served as a modulus (standard), whose value was called 10.

The data from all six experiments confirm the general shape of Thomas's equal-volume contours. Magnitude estimations of volume had quite similar values for all tones taken from the same contour. The averaged values from the six experiments indicate that the subjective magnitude associated with each of Thomas's equal-volume contours is approximately twice that of the next smaller contour. From these contour values it follows that volume grows as a power function of sound pressure, and that the exponent increases markedly with frequency.

The power functions showing the growth of volume with sound pressure converge toward a common value at a level of 140 db. Volume behaves as a prothetic continuum and is not a power function of frequency.

This article will appear in a forthcoming issue of the American Journal of Psychology.

PNR-263 Comments on the Measurement of the Relative Size of d-c Potentials and Microphonics in the Cochlea. G. v. Békésy.

This Letter to the Editor will appear in the Journal of the Acoustical Society of America in January 1962.

PNR-265 Can We Feel the Nervous Discharges of the End Organs during Vibratory Stimulation of the Skin? G. v. Békésy.

The vibratory pitch sensation is a complicated function of both the frequency and the amplitude of the vibrations, and frequency discrimination on the skin is thus inaccurate within a range of one or two octaves. Rutherford's telephone theory for pitch discrimination does not describe the pitch of vibratory sensations.

PNR-266 The Scaling of Subjective Roughness and Smoothness. S. S. Stevens and Judith Rich.

Preliminary experiments showed that the apparent roughness and smoothness of 12 samples of emery cloths could be scaled by magnitude estimation. Two 7-point category scales produced results typical of prothetic continua: the plot of the category scale vs. the ratio scale is concave downward, but the curvature depends upon the spacing of the stimuli.

Magnitude estimations of roughness and smoothness produced straight lines when plotted (log-log) against grit number. In order to determine the exponents of these power functions more precisely, two additional experiments were run with magnitude estimation and one with cross-modality matching against loudness. All three experiments gave results that were power functions of grit number with exponents in the vicinity of -1.5 for roughness and +1.5 for smoothness. (Grit number is proportional to the reciprocal of particle size.) In terms of the average diameter D of the abrasive particles, roughness R, in units of ruks (1 unit = roughness produced by grit 320), is given by

$$R = 106.5D^{1.5}.$$

Although judgments of smoothness turned out to be nearly proportional to the reciprocals of the judgments of roughness, this reciprocality was most clearly evident when 10 Os adjusted the intensity of a noise to produce a loudness that matched the apparent smoothness. The cross-modality matches also confirmed the exponents determined by magnitude estimation.

PNR-267 <u>Concerning the Pleasures of Observing, and the Mechanics of the Inner Ear</u>. G. v. Békésy.

This article will be published as a Nobel Lecture in Les Prix Nobel en 1961.

SPECIAL ACTIVITIES

Georg von Békésy was the recipient of the 1961 Nobel Prize in Medicine for "his discoveries concerning the physical mechanisms of stimulation within the cochlea." This climaxes the many honors Dr. Békésy has received since he came to the Psycho-Acoustic Laboratory in 1947. Almost simultaneously with the announcement of the Nobel Prize, Dr. Békésy was honored by an award from the Deafness Research Foundation.

S. S. Stevens gave an invited address at the meetings of the American Psychological Association. The address, entitled "The Surprising Simplicity of Sensory Metrics," was made in response to his having received the Distinguished Scientific Contribution Award in 1960.

RESEARCH IN PROGRESS

1. <u>Fractionation of brightness under conditions of simultaneous contrast</u>. J. C. Stevens. One half of the apparatus described under item 2 in this report was used to repeat and extend our experiments on contrast. With the right eye the observer viewed a pair of concentric fields. His task was to adjust the luminance of one of the fields so that its brightness appeared to be some fraction or multiple of the other field. A dozen observers participated in each of three experiments.

(1) In the first experiment the observer attempted to adjust the inner field so that it appeared to be 1/2, 1/4, 1/10, and 1/20 as bright as the surround. These judgments were performed at each of seven levels of the surround between 40 and 100 db re 10^{-10} lambert. To control the adaptation, the observer was dark-adapted before the experiment, and the fields were exposed for 1.5 sec with intervals of 8 sec between exposures. The results were generally consistent with the earlier findings. With a bright surround, the brightness of a target grows as a power function of its luminance. The exponent is very much larger than that of the standard bril function (determined without contrast), and the size of the exponent increases with increasing luminance of the surround, at least up to about 80 db. With very bright surrounds, the functions appear so steep that they are difficult to determine with precision, and the results were not sufficiently clearcut to decide whether the exponent continues to increase beyond surround levels of about 80 db.

(2) In the second experiment the observer set the luminance of the surround so that it looked twice or ten times as bright as the inner disk. The results were quite consistent with those of the first experiment.

(3) The third experiment was like the second, except that the target and its surround were on continuously until the observer finished his adjustment. The purpose was to learn whether the increased light adaptation would play a major role in determining the slope of the brightness function under conditions of simultaneous contrast. Over the range explored (35 to 95 db) there was a negligible effect produced by changing the conditions of adaptation from periodic to continuous exposure of the fields. The average settings in the two experiments were practically the same.

2. Apparatus for the Study of Contrast. R. Gerbrands, J. C. Stevens, and S. S. Stevens. An apparatus was constructed for the study of simultaneous brightness contrast (see Fig. 1). This apparatus features a pair of large Lummer-Brodhun cubes, each of which serves to produce a pair of concentric fields (an inner disk and an outer surround, similar to the two fields seen in a Macbeth Illuminometer). With the left eye the observer sees the inner and outer fields produced with one of the cubes, and with the other eye he sees the two fields produced with the other cube. The figure shows only the half of the apparatus that is used to stimulate the left eye; the other half is identical, except that the parts are reversed, left for right.

The four fields are produced by four identical projectors. With 300-watt lamps in the projectors, the fields have a maximum luminance of about 110 db re 10^{-10} lambert. For most experiments, 100-watt lamps are adequate. By means of mirrors and tubes, the beams are directed to the appropriate part of the cube. The flux from each projector can be independently controlled with neutral density filters and by an aperture of continuously variable size. Each aperture alone permits a continuous variation of more than 40 db in the luminance of a field. Both the observer and the experimenter can control each of the four apertures by means of knobs. The luminances of the inner and outer fields can also be attenuated by the same factor simultaneously by inserting a neutral density filter between the cube and the observer. Ground glass diffusion screens inserted between the cube and the light source insure uniformity of luminance over each field.

For convenient monitoring during an experiment, the photosensitive element of a Welsh Densichron can be placed at a window in any of the boxes containing the mirrors and filters. Since readings taken at this point are proportional to the luminance of the fields seen by the observer, a change in the luminance of one or more of the fields can be registered directly, in decibels, on the logarithmic scale of the Densichron.

The apparatus is convenient for interocular matching in studies related to brightness contrast. The observer's task may be to match the apparent brightness of the two inner fields when the outer fields have different luminance levels. By this procedure one can determine the combinations of target and surround luminance that leave invariant the brightness of the inner disk. Studies of this kind will be made in order to test an equation for simultaneous contrast that was published earlier (J. opt. Soc. Amer., 1960, 50, p. 1139).

With the neutral filters replaced by various selective filters, the apparatus may also be used to study color induction.

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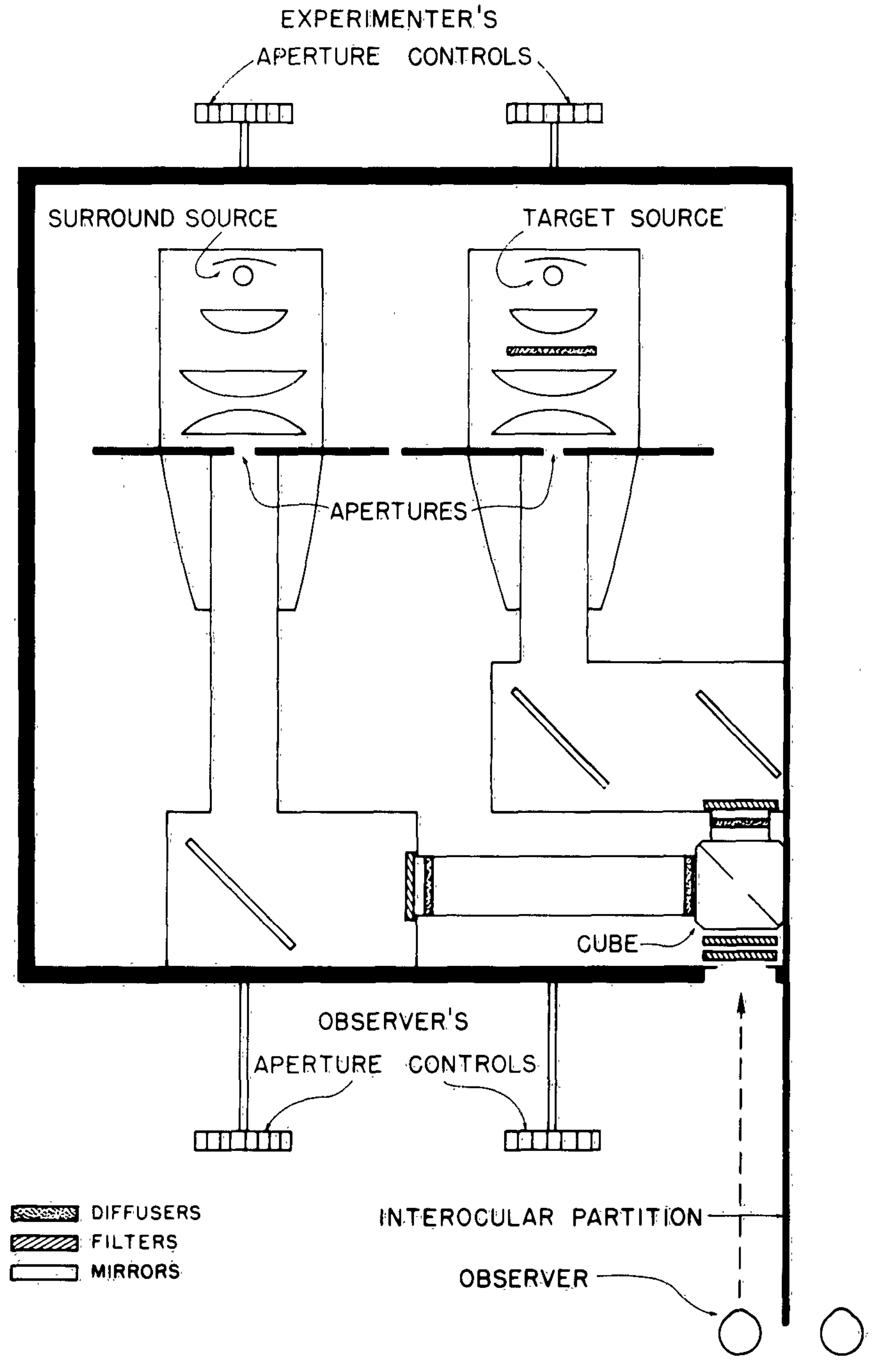
Details regarding the construction of the Lummer-Brodhun cubes: each cube is made from two right angle prisms. These prisms are of optical glass and have polished surfaces. The right angle faces are



APPARATUS FOR THE STUDY OF CONTRAST

47 x 47 mm. The long face of one of the prisms is treated with hydrofluoric acid so that all but a carefully masked central portion of the surface is etched away. This masked portion is an ellipse 22 x 15.5 mm. The etching, in effect, raises the ellipse above the rest of the surface.

The two prisms are then cemented together, long face to long face, in such a way that only the elliptical surface of the etched prism makes optical contact with the surface of the other prism. The quantity of cement used must be just enough to spread evenly over the elliptical surface. An excess of cement will spill over the area and will result in a non-circular field when the ellipse is viewed at 45°. The cement used is Canada Balsam, treated in an oven at high temperature, so that it will solidify at room temperature. In the cementing process both the cement and the prisms are heated to a temperature of 150°C. The hot cement is then applied to the hot prisms, one prism is placed on top of the other, and both allowed to cool slowly to room temperature. After cooling, the joint formed by the surfaces of the prisms is sealed with a strip of tape. The cube formed by the cemented prisms is then ready for use in the apparatus described above.

3. Subjective Brightness of Visual Stimuli of Various Durations and Luminances. T. Aiba. The relation between duration and apparent brightness of flashes produced by a glow-modulator tube will be determined by the methods of matching and magnitude estimation. The objects of this investigation are threefold.

First, the validity of Bloch's law will be examined at several energy levels. Although Bloch's law has been found to hold true when various threshold measures were used, evidence for its validity for flashes at suprathreshold levels is scanty and, at best, based on a few selected energy levels. Second, the brightness function for flashes of varying duration will be determined. If the flash duration and luminance are perfectly reciprocal (i.e. if Bloch's law holds), then the power function that has been found for flashes of a fixed duration will presumably also hold for flashes of varying duration. But in the region where Bloch's law does not hold exactly, the exponent of the function is expected to be different. Third, the ranges of luminance and duration that cause the so-called "Broca-Sulzer effect" will be examined. Although this effect has been rather well established, there is some doubt whether it shows up at all intensities. The optimal durations for producing the effect at various intensity levels also need to be more clearly determined.

4. Subjective Brightness during Dark Adaptation. G. van den Brink. The purpose is to trace the time course followed by the brightness of suprathreshold stimuli during dark adaptation. After the right eye has been light adapted, the subjective brightness of various luminances will be measured as a function of the time in the dark by means of a brightness comparison with stimuli presented to the dark-adapted left eye. During the process of dark adaptation, the brightness of the target observed

with the right eye increases. Periodically, stimuli that are subjectively weaker than the comparison stimulus in the left eye will be presented to the right eye. The times at which stimuli in the left and right eyes become equal in subjective brightness will be measured for different luminances of the right-eye stimulus.

5. Studies of Loudness, Softness, Distance, and Reciprocality. M. Guirao. This study concerns two problems: (1) whether the instructions to judge "distance" produce different results from instructions to judge loudness and softness; and (2) under what conditions judgments of softness are the reciprocal of judgments of loudness.

Fourteen experiments were carried out. The experiments involved judgments of loudness, softness, and "distance" of pure tones and white noise. The methods used included magnitude estimation, magnitude production, and category production. In the experiments involving judgments of "distance," the results were essentially identical to the results obtained with estimates of softness: they were approximately the reciprocal of the estimates of loudness. Reciprocality between estimates of loudness and softness was shown more precisely with the method of magnitude production than with the method of magnitude estimation.

6. The Transition Level: A Discontinuity in the Intensitive Difference Limen. L. McMahon. Experiments by D. Greenwood indicate that the masked threshold for a pure tone in the presence of a narrow band of noise is proportional to the sensation level of the noise up to a certain level called the transition level. At this point, the masked threshold drops about 3 db; above the transition level the masked threshold is again proportional to the noise intensity. Preliminary experiments by Greenwood showed that this discontinuity at a transition level also occurred when the masking stimulus was a pure tone of the same frequency as the masked tone; in this case the experiment could be considered an investigation of the intensitive difference threshold (PNM-91, 15 May 1961, p. 8).

Preliminary results by the present experimenter (with one observer) show that the discontinuity at the transition level can be demonstrated by two methods: (1) for a fixed level of the steady (masking) tone, the observer adjusts the size of the increment until it is just audible; (2) for a fixed ratio of the increment to the sound pressure of the steady tone, the observer adjusts the level until the increment is just audible. Results of the two methods agree in showing a transition level at which the ratio of increment to steady level drops 6 to 8 db.

With more satisfactory apparatus, now being designed, the parameters affecting this discontinuity in the masked threshold will be investigated more fully.

7. A Test of Binocular Summation. L. R. Hammer, J. D. Kieffer, and A. W. Slawson. A preliminary experiment has suggested that magnitude estimations of stimuli viewed binocularly do not differ significantly from the estimations of the same stimuli viewed with only one eye.

Subjects were dark-adapted and seated in a light-proof booth. They were asked to judge the brightness of a round 3-degree spot whose luminance was changed in irregular order within the range of approximately 53 to 103 db above 10^{-10} lamberts. An experimenter in the booth operated shutters that allowed vision with the right eye only, the left eye only, or with both eyes. Each stimulus lasted 1 sec. The observer was asked to assign numbers proportional to the apparent brightness, beginning with any number he felt to be appropriate. Regardless of whether one or two eyes were employed, the magnitude estimates of brightness grew as a power function of stimulus luminance with an exponent of approximately .35, and the intercepts of the power functions were not significantly different from one another.

8. Subjective Saturation of a Color. D. W. Panek. An attempt will be made to determine the relation between subjective estimates of degree of saturation and the actual proportion of a hue added to a gray. To this end, a mixer has been constructed which, by mixing a colored and a gray paper, presents to the subject a colored spot which is continuously variable in saturation.

CHECK-LIST OF REPORTS

issued by the

PSYCHO-ACOUSTIC LABORATORY, HARVARD UNIVERSITY
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No.	Title	Published by	Authors
PNR-151*	Preparatory and air-driven micro-manipulators for electro-physiology	Rev. sci. Instruments, 1956, 27, 690-692	G. v. Békésy
PNR-152	The masking of speech by repeated bursts of noise	J. acoust. Soc. Amer., 1954, 26, 1053-55	I. Pollack
PNR-153	Auditory sensitization	J. acoust. Soc. Amer., 1954, 26, 1064-1070	J. R. Hughes
PNR-154	Decibels of light and sound	Physics Today, 1955 8(10), 12-17	S. S. Stevens
PNR-155	On the averaging of data	Science, 1955, 121, 113-116	S. S. Stevens
PNR-156	Tonal monaural diplaucusis	J. acoust. Soc. Amer., 1955, 27, 365-372	W. D. Ward
PNR-157	Factors determining the sound attenuation produced by earphone sockets	J. acoust. Soc. Amer., 1955, 27, 146-154	J. Zwislocki
PNR-158	Paradoxical direction of wave travel along the cochlear partition	J. acoust. Soc. Amer., 1955, 27, 137-145	G. v. Békésy
PNR-159	On the halving and doubling of white noise	J. acoust. Soc. Amer., 1955, 27, 329-331	E. C. Poulton S. S. Stevens
PNR-160	Bibliography on Hearing	Cambridge: Harvard University Press, 1955	S. S. Stevens J. C. G. Loring Dorothy Cohen
PNR-161	The development of a semiplastic earphone socket	J. acoust. Soc. Amer., 1955, 27, 155-161	J. Zwislocki
PNR-162	El oído y la vista [The ear and the eye]. In Act. Prim. Congr. Extraord. Soc. Internat. Audiol.	Buenos Aires, 1954, pp. 408-416	S. S. Stevens

*The list containing PNR-1 to PNR-150 is available on request.

No.	Title	Published by	Authors
PNR-163	The estimation of loudness by unpracticed observers	J. exp. Psychol., 1956, 51, 71-78	S. S. Stevens E. C. Poulton
PNR-164	The apparent reduction of loudness: a repeat experiment	J. acoust. Soc. Amer., 1955, 27, 326-328	S. S. Stevens M. S. Rogers R. Herrnstein
PNR-165	Semiplastic earplugs	J. acoust. Soc. Amer., 1955, 27, 460-465	J. Zwislocki
PNR-166	A note on recent developments in auditory theory	Proc. Nat. Acad. Sci., 1954, 40, 508-512	E. G. Wever M. Lawrence G. v. Békésy
PNR-167	The moments of sample information when the alternatives are equally likely. In Information Theory in Psychology: Problems and Methods	Glencoe, Ill.: Free Press, 1955, pp. 101-108	M. S. Rogers B. F. Green
PNR-168	The measurement of loudness	J. acoust. Soc. Amer., 1955, 27, 815-829	S. S. Stevens
PNR-169	The direct estimation of sensory magnitudes -- loudness	Amer. J. Psychol., 1956, 69, 1-25	S. S. Stevens
PNR-170	Ear protectors. In Handbook of Noise Control	New York: McGraw-Hill, 1957, 27 pp.	J. Zwislocki
PNR-171	Beitrag zur Frage der Frequenzanalyse in der Schnecke [On the question of frequency analysis in the cochlea]	Arch. Ohr-usw. Heilk., 1955, 167, 238-255	G. v. Békésy
PNR-172	Discriminative skill and discriminative matching in perceptual recognition	J. exp., Psychol., 1955, 49, 187-192	J. S. Bruner G. A. Miller C. Zimmerman
PNR-173	Hearing and speech. In American Institute of Physics Handbook	New York: McGraw-Hill, 1957, pp. 123-133	E. B. Newman
PNR-174	The magical number 7 $\pm$ 2	Psychol. Rev., 1956, 63, 81-97	G. A. Miller

No.	Title	Published by	Authors
PNR-175	Human skin perception of traveling waves similar to those on the cochlea	J. acoust. Soc. Amer., 1955, 27, 830-841	G. v. Békésy
PNR-176	Psychophysical effects of noise	Noise Control, 1955, 1(4), 16-21	E. B. Newman
PNR-177	The design and testing of earmuffs	J. acoust. Soc. Amer., 1955, 27, 1154-1163	J. Zwislocki
PNR-178	Pendulums, traveling waves and the cochlea	16-mm color film (55 minutes) available on loan	G. v. Békésy R. L. Grason
PNR-179	Current status of theories of hearing	Science, 1956, 123, 779-783	G. v. Békésy
PNR-180	The perception of speech. In For Roman Jakobson	The Hague: Mouton & Co., 1956, pp. 353-360	G. A. Miller
PNR-181	The calculation of the loudness of complex noise	J. acoust. Soc. Amer., 1956, 28, 807-832	S. S. Stevens
PNR-182	Just noticeable differences in dichotic phase	J. acoust. Soc. Amer., 1956, 28, 860-864	J. Zwislocki R. S. Feldman
PNR-183	Response-sequences and the hypothesis of the neural quantum	Amer. J. Psychol., 1957, 70, 512-527	U. Neisser
PNR-184	Estimations of loudness by a group of untrained observers	Amer. J. Psychol., 1957, 70, 600-605	J. C. Stevens E. Tulving
PNR-185	Human memory and the storage of information. In Information Theory	IRE Trans., Sept. 1956, IT2(3), 129-137	G. A. Miller
PNR-186	Ratio scales and category scales for a dozen perceptual continua	J. exp. Psychol., 1957, 54, 377-411	S. S. Stevens E. H. Galanter
PNR-187	Simplified model to demonstrate the energy flow and formation of traveling waves similar to those found in the cochlea	Proc. Nat. Acad. Sci., 1956, 42, 930-944	G. v. Békésy

No.	Title	Published by	Authors
PNR-188	On the psychophysical law	Psychol. Rev., 1957, 64, 153-181	S. S. Stevens
PNR-189	Adaptation level vs. the relativity of judgment	Amer. J. Psychol., 1958, 71, 633-646	S. S. Stevens
PNR-190	Problems and methods of psychophysics	Psychol. Bull., 1958, 54, 177-196	S. S. Stevens
PNR-191	Some measurements of the impedance at the eardrum	J. acoust. Soc. Amer., 1957, 29, 349-356	J. Zwislocki
PNR-192	Critical bandwidth in loudness summation	J. acoust. Soc. Amer., 1957, 29, 548-557	E. Zwicker G. Flottorp S. S. Stevens
PNR-193	Sensations on the skin similar to directional hearing, beats, and harmonics of the ear	J. acoust. Soc. Amer., 1957, 29, 489-501	G. v. Békésy
PNR-194	Concerning the form of the loudness function	J. acoust. Soc. Amer., 1957, 29, 603-606	S. S. Stevens
PNR-195	Calculating loudness	Noise Control., 1957, 3(5), 11-22	S. S. Stevens
PNR-196	The ear	Sci. American, 1957, 197(2), 66-78	G. v. Békésy
PNR-197	In search of the bone-conduction threshold in a free sound field	J. acoust. Soc. Amer., 1957, 29, 795-804	J. Zwislocki
PNR-198	Some similarities between hearing and seeing	Laryngoscope, 1958, 68(3), 508-527	S. S. Stevens
PNR-199	The variability of auditory and visual thresholds in time	J. gen. Psychol., 1955, 52, 111-147	M. Wertheimer
PNR-200	Neural volleys and the similarity between some sensations produced by tones and skin vibrations	J. acoust. Soc. Amer., 1957, 29, 1059-1069	G. v. Békésy

No.	Title	Published by	Authors
PNR-201	Measurement, psychophysics and utility. In *Measurement: Definitions and Theories*	New York: Wiley, 1959, pp. 18-64	S. S. Stevens
PNR-202	Some impedance measurements on normal and pathological ears	*J. acoust. Soc. Amer.*, 1957, 29, 1312-1317	J. Zwislocki
PNR-203	Ear protection: effectiveness versus comfort	*Noise Control*, 1958 4(6), 14-15	J. Zwislocki
PNR-204	On the effect of practice and motivation on the threshold of audibility	*J. acoust. Soc. Amer.*, 1958, 30, 254-262	J. Zwislocki F. Maire A. S. Feldman H. Rubin
PNR-205	Fenestration of the labyrinth: A bibliography (revision of PNR-143)	PAL, 15 Sept. 1957	G. Kelemen
PNR-206	Threshold changes at 4 Kc/s produced by bands of noise	*Acta oto-laryng. Stockh.*, 1957, 47, 496-509	R. Hinchcliffe
PNR-207	On the minimum audible angle	*J. acoust. Soc. Amer.*, 1958, 30, 237-246	A. W. Mills
PNR-208	Stimulus spacing and the judgment of loudness	*J. exp. Psychol.*, 1958, 56, 246-250	J. C. Stevens
PNR-209	A scale of apparent intensity of electric shock	*J. exp. Psychol.*, 1958, 56, 328-335	S. S. Stevens A. S. Carton G. M. Shickman
PNR-210	Measurement and man	*Science*, 1958, 127, 383-389	S. S. Stevens
PNR-211	Ear protection	*Laryngoscope*, 1958 68(3), 486-497	J. Zwislocki
PNR-212	Introduction and script: Pendulums, traveling waves and the cochlea	PAL, 27 Dec. 1957; *Laryngoscope*, 1958, 68(3), 317-328	G. v. Békésy
PNR-213	Funneling in the nervous system and its role in loudness and sensation intensity on the skin	*J. acoust. Soc. Amer.*, 1958, 30, 399-412	G. v. Békésy

No.	Title	Published by	Authors
PNR-214	Finger span: Ratio scale, category scale and jnd scale	J. exp. Psychol., 1959, 57, 91-95	S. S. Stevens Geraldine Stone
PNR-215	Tactile vibration: Dynamics of sensory intensity	J. exp. Psychol., 1959, 57, 210-218	S. S. Stevens
PNR-216	Cross-modality validation of subjective scales for loudness, vibration, and electric shock	J. exp. Psychol., 1959, 57, 201-209	S. S. Stevens
PNR-217	On the problem of validating a method for calculating loudness	PAL May 1958 ISO/TC/43, WG-5	S. S. Stevens
PNR-218	Similarities between hearing and skin sensations	Psychol. Rev., 1959, 66, 1-22	G. v. Békésy
PNR-219	Subjective intensity of coffee odor	Amer. J. Psychol., 1960, 73, 424-428	T. S. Reese S. S. Stevens
PNR-220	Critical bands and the loudness of complex sounds near threshold	J. acoust. Soc. Amer., 1959, 31, 365-370	B. Scharf
PNR-221	The growth of subjective magnitude with stimulus intensity. In Second ONR Symposium on Physiological Psychology	Pensacola, Fla., March 1958, pp. 41-49	J. C. Stevens S. S. Stevens
PNR-222	The perception of repetition rate	J. exp. Psychol., 1959, 58, 433-440	J. C. Stevens G. M. Shickman
PNR-223	The loudness of complex sounds as a function of the number of components	J. acoust. Soc. Amer., 1959, 31, 783-786	B. Scharf
PNR-224	Synchronism of neural discharges and their demultiplication in pitch perception on the skin and in hearing	J. acoust. Soc. Amer., 1959, 31, 338-349	G. v. Békésy
PNR-225	Scales of apparent force	J. exp. Psychol., 1959, 58, 405-413	J. C. Stevens J. D. Mack

No.	Title	Published by	Authors
PNR-226	Growth of sensation on seven continua as measured by force of handgrip	J. exp. Psychol., 1960, 59, 60-67	J. C. Stevens J. D. Mack S. S. Stevens
PNR-227	On the validity of the loudness scale	J. acoust. Soc. Amer., 1959, 31, 995-1004	S. S. Stevens
PNR-228	Neural funneling along the skin and between the inner and outer hair cells of the cochlea	J. acoust. Soc. Amer., 1959, 31, 1236-1250	G. v. Békésy
PNR-229	Experimental models of the cochlea with and without nerve supply. In Neural Mechanisms of the Auditory and Vestibular Systems	Springfield, Ill.: Thomas, 1960, pp. 3-20	G. v. Békésy
PNR-230	The quantification of sensation	Daedalus, Fall 1959, 88(4), 606-621	S. S. Stevens
PNR-231	Auditory facilitation following stimulation at low intensities	J. acoust. Soc. Amer., 1960, 32, 670-681	H. Rubin
PNR-232	The form of the loudness function near threshold. In Proc. 3rd Int. Congr. Acoustics.	Amsterdam: Elsevier (in press)	B. Scharf J. C. Stevens
PNR-233	Über die Gleichartigkeit einiger nervöser Prozesse beim Hören und Vibrationssinn. In Proc. 3rd Int. Congr. Acoustics	Amsterdam: Elsevier (in press)	G. v. Békésy
PNR-234	Warmth and cold: dynamics of sensory intensity	J. exp. Psychol., 1960, 60, 183-192	J. C. Stevens S. S. Stevens
PNR-235	Lateralization of high-frequency tones	J. acoust. Soc. Amer., 1960, 31, 132-134	A. W. Mills
PNR-236	Psychophysics of sensory function. In Sensory Communication	New York: Tech. Press and Wiley, 1961, pp. 1-33; Amer. Scientist, 1960, 48, 226-253	S. S. Stevens
PNR-237	The auditory input-output function. In Proc. 3rd Int. Congr. Acoustics	Amsterdam: Elsevier (in press)	S. S. Stevens

No.	Title	Published by	Authors
PNR-238	Is there a quantal threshold? In Sensory Communication	New York: Tech. Press and Wiley, 1961, pp. 806-813	S. S. Stevens
PNR-239	On the new psychophysics	Scand. J. Psychol., 1960, 1, 27-35	S. S. Stevens
PNR-240	Ratio scales, partition scales and confusion scales. In Psychological Scaling: Theory and Applications	New York: Wiley, 1960, pp. 49-66	S. S. Stevens
PNR-241	The influence of inhibition on the sensation pattern of the skin and the eye. In Symposium on Cutaneous Sensitivity	Fort Knox, Ky.: U.S. Army Med. Res. Lab. Report No. 424, 1960, pp. 50-62	G. v. Békésy
PNR-242	Voice level: Autophonic scale, perceived loudness, and effects of sidetone	J. acoust. Soc. Amer., 1961, 33, 160-167	H. L. Lane A. C. Catania S. S. Stevens
PNR-243	Neural inhibitory units of the eye and skin. Quantitative description of contrast phenomena	J. opt. Soc. Amer., 1960, 50, 1060-1070	G. v. Békésy
PNR-244	The binaural summation of loudness	J. acoust. Soc. Amer., 1960, 32, 1337-1344	G. S. Reynolds S. S. Stevens
PNR-245	Physiological zero and the psychophysical law. In Proc. 16th Int. Congr. Psychology	(in press)	J. C. Stevens S. S. Stevens
PNR-246	The dynamics of visual brightness	PAL, August, 1960	S. S. Stevens J. C. Stevens
PNR-247	The pitch sensation and its relation to the periodicity of the stimulus	J. acoust. Soc. Amer., 1961, 33, 341-348	G. v. Békésy
PNR-248	To honor Fechner and repeal his law	Science, 1961, 133, 80-86	S. S. Stevens
PNR-249	Toward a resolution of the Fechner-Thurstone legacy	Psychometrika, 1961, 26, 35-47	S. S. Stevens

No.	Title	Published by	Authors
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PNR-251	Are surgical experiments on human subjects necessary?	Laryngoscope, 1961, 71, 367-376	G.v. Békésy
PNR-252	Auditory masking and the critical band	J. acoust. Soc. Amer., 1961, 33, 484-502	D. D. Greenwood
PNR-253	Procedure for calculating loudness, Mark VI	PAL, 1 March 1961 ISO/TC/43 WG-5	S. S. Stevens
PNR-254	Concerning the fundamental component of periodic pulse patterns and modulated vibrations observed in the cochlear model with nerve supply	J. acoust. Soc. Amer., 1961, 33, 888-896	G. v. Békésy
PNR-255	The dynamics of subjective warmth and cold. In Fourth Symposium on Temperature	New York: Reinhold (in press)	J. C. Stevens S. S. Stevens
PNR-256	Surprising simplicity of sensory metrics	Amer. Psychologist,	S. S. Stevens
PNR-257	Abweichungen vom Ohm'schen Gesetz der Frequenzauflösung beim Hören	Akust. Beih., Acustica	G. v. Békésy
PNR-258	The gap between the hearing of external and internal sounds	J. exp. Biol.,	G. v. Békésy
PNR-259	The quantification of tonal volume	Amer. J. Psychol.,	H. S. Terrace S. S. Stevens
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